

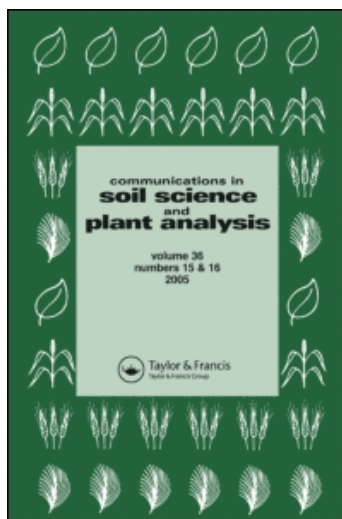
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A. K. Alva ^a; T. Hodges; R. A. Boydston ^a; H. P. Collins ^a

^a USDA-ARS-PWA, Prosser, WA, U.S.A.

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EFFECTS OF IRRIGATION AND TILLAGE PRACTICES ON YIELD OF POTATO UNDER HIGH PRODUCTION CONDITIONS IN THE PACIFIC NORTHWEST

**A. K. Alva,^{1,*} T. Hodges,² R. A. Boydston,¹ and
H. P. Collins¹**

¹USDA-ARS-PWA, Vegetable and Forage Crop Production
Research Unit, 24106 North Bunn Road, Prosser, WA 99350

²Agricultural Systems Consultant, 14314 SW Allen Blvd.,
#317, Beaverton, OR 97005

ABSTRACT

The soil and climate conditions prevalent in the Pacific Northwest region are favorable for production of high potato (*Solanum tuberosum* L.) yields. Much of this production occurs on coarse, low organic matter, sandy soils which can be subject to wind and water erosion, and excessive leaching of water and soluble agrichemicals below the root zone, particularly when irrigation is not managed adequately. Tuber production and quality are adversely impacted when potatoes are subject to water stress. Therefore, optimal irrigation scheduling is important to support high production of good quality tubers and to minimize potential adverse impacts on water quality. Effects of two irrigation regimes and three tillage practices on production of two potato varieties were studied under four years rotation with either corn (*Zea mays*

*Corresponding author. Fax: (509) 786-9277; E-mail: aalva@pars.ars.usda.gov

L.) or wheat (*Triticum aestivum* L.). In two out of three years, as compared to irrigation to replenish full evapotranspiration (ET), deficit irrigation (85% of ET) decreased total tuber yield by 8 to 11% and 10 to 17%, and U.S. No. 1 tuber yield by 5 to 17% and 16 to 25%, in Russet Burbank and Hilite Russet cultivars, respectively. Tillage treatments evaluated were (i) conventional including raised ridges with dammer-dike; (ii) optimal, i.e., lower depth of the tillage and shallow furrow; and (iii) reduced tillage, i.e., flat planting. During the first two years of the study, the effects of tillage treatments were non-significant on the total as well as U.S. No. 1 tuber yield in both cultivars. On the third year, the tuber yield was significantly lower in flat planting treatment as compared to that in the other tillage treatments. This study demonstrated that in coarse textured soils with adequate water infiltration, excessive tillage and/or dammer-diking may not benefit potato production.

INTRODUCTION

In 1999, potato (*Solanum tuberosum* L.) cultivation in the Pacific Northwest, (PNW; including Idaho, Washington, and Oregon) extended over 256 thousand hectares with a total production of 11.7×10^6 Mg. The PNW potato industry represents 45% of the total US potato acreage and 54% of the total production (www.nass.usda.gov). The intensively irrigated Columbia Basin region of the Pacific Northwest produces the highest yield per unit area in the country, i.e., 78 Mg ha^{-1} , as compared to the national average of 38 Mg ha^{-1} .

Water and nitrogen (N) are the two major inputs for potato production (1). Inadequate management of these inputs impacts tuber production, quality, and net returns (2–7). Evaluation of the effects of irrigation at 1.0, 1.2, or 1.4 fold of evapotranspiration (ET) and in-season frequencies of fertigation on yields of Russet Burbank planted in a Declo silt loam (coarse, loamy, mixed mesic, Durixerollic Calciorthid) soil, showed the best yield by scheduling irrigation to replenish 100% ET (7). They also showed a significant decrease in yield with excessive irrigations, i.e., in excess of ET. The highest tuber yield (40 Mg ha^{-1}) was obtained with irrigation to replenish full ET and in-season application of 132 kg N ha^{-1} as fertigation with three biweekly applications. Westermann and Sojka (8) reported a 9% greater tuber yield when 220 kg ha^{-1} N was banded rather than broadcasting to Russet Burbank potato planted on a Portneuf silt loam (coarse, silty, mixed mesic Durixerollie Calciorthid).

Potato production in southeast Washington is predominately on coarse, sandy soils (9). These soils typically have organic matter $\leq 0.5\%$ and low water-holding

capacity. The available soil moisture content of these sandy soils is approximately 6% (gravimetric basis) (A.K. Alva, unpublished data). Excess application and/or poor management of water and nitrogen (N) fertilizer can result in rapid deep percolation of water and N below the rootzone, thus became unavailable to the plants. Therefore, efficient management of both of these inputs is important to maximize uptake efficiency and minimize losses and adverse environmental impacts. Recent random surveys of drinking water quality evaluations conducted in the Columbia Basin have shown that 30 to 33% of all groundwater sources being sampled contained $\text{NO}_3\text{-N}$ concentrations in excess of maximum contaminant level (MCL) for drinking water standards [10 mg L^{-1} (10)]. The objective of this study was to evaluate the effects of different tillage practices and irrigation regimes on potato production in a sandy soil under sprinkler irrigation.

MATERIALS AND METHODS

A four-year rotation project began in 1992, on a Quincy sand (0.5% organic matter, mixed, mesic Xeric Torripsamments) site in Benton County, WA, to study the effects of tillage and irrigation regimes on a full season, indeterminate potato cultivar, i.e., Russet Burbank, and an early maturing, determinate cultivar, i.e., Hilite Russet. The site had not been previously farmed and soil organic matter content ranged from 0.4 to 0.5%. The tillage treatments evaluated were (i) conventional—where the soil was ripped, disked, packed, and rototilled, and potato beds were prepared with high hill and deep dammer-dike (reservoir tillage) to conserve soil moisture; (ii) modified optimal—very similar to the conventional except that the bed was medium height, flat, and with shallow dammer-dike; (iii) flat planting—tillage was further reduced and no hill was made during planting. The typical cropping rotation was corn (*Zea mays* L.)—potato—winter wheat (*Triticum aestivum* L.). Two irrigation regimes, based on crop evapotranspiration (ET), were evaluated using a linear move sprinkler system: (i) full ET—each irrigation replenished 100% ET; and (ii) deficit irrigation—each irrigation replenished 85% of ET. The experiment was conducted with a randomized block design with four replications.

Cut potato seed pieces were planted at a rate of $4.56 \text{ plants m}^{-2}$ ($45,600 \text{ plants ha}^{-1}$) at 15 cm depth. Recommended standard best management practices were followed. Within each potato plot, a subsample of 3 rows of 3 m each were dug. The total fresh weight of the tuber from the sampled area was recorded. A subsample was taken from the yield samples for U.S. No. 1 tuber yield determination. The data were analyzed by analysis of variance (ANOVA) procedure using SAS program (11). The statistical difference between the means was calculated by least significant difference (LSD) procedure, at 95% probability level.

RESULTS AND CONCLUSIONS

Although this experiment began in 1992, the data for 1993 through 1995 were discussed in this manuscript. Irrigation to replenish full ET required a total water application of 492, 608, and 588 mm for the 1993, 1994, and 1995 growing seasons, respectively. The weather data was used from the weather station located adjacent to the field site, as a part of Washington State Public Agriculture weather service (PAWS; <http://Paws.prosser.wsu.edu>). The growing season of 1994 was relatively warm with 82 days when daily maximum temperatures exceeded 30°C, unlike 44 and 56 days during 1993 and 1995 growing season, respectively (Fig. 1). In 1994, July and August were extremely warm with several days of maximum temperature approaching or exceeding 40°C. Accordingly, ET was much greater in 1994 as compared to the other two years (Fig. 2). The cumulative ET during the growth period was 831 mm in 1994, unlike 756 and 769 during 1993 and 1995, respectively.

The irrigation effect was significant on total, as well as U.S. No. 1 tuber yield for two out of three years (Table 1). The variety effect was also significant during two out of three years on the total tuber yield, but only on one year on the U.S. No. 1 tuber yield. The tillage effect was significant on total tuber yield only in one out of three years but was non-significant on the U.S. No. 1 tuber yield.

Maintaining adequate available soil moisture is extremely critical for potato yields. The shallow rooting of potato (12,13) provides only limited soil volume to extract water and nutrients. Therefore, irrigation management is quite critical to replenish the soil moisture within the rooting depth. Effect of irrigation was non-significant on the tuber yield of both cultivars in 1993. During the

Table 1. Analysis of Variance Summary for Total Tuber and U.S. No. 1 Tuber Yields of Two Potato Cultivars as Influenced by Irrigation and Tillage Treatments

Source	DF	Total Tuber Yield (Mg ha ⁻¹)			No. 1 Tuber Yield (Mg ha ⁻¹)		
		1993	1994	1995	1993	1994	1995
Irrigation (I)	1	0.3741	0.0001	0.0169	0.6616	0.0008	0.0095
Tillage (T)	2	0.9762	0.0064	0.1489	0.7654	0.4925	0.1098
Variety (V)	1	0.4407	0.0001	0.0001	0.2431	0.0001	0.2458
I × T	2	0.0192	0.0258	0.1720	0.0859	0.1548	0.8028
T × V	2	0.0846	0.4848	0.0001	0.2933	0.3798	0.0113
I × V	1	0.8480	0.1483	0.0829	0.8325	0.0151	0.3851

I1 = irrigation to replenish the ET; I2 = irrigation to replenish 85% of ET; T1 = conventional tillage; T2 = modified tillage; T3 = reduced tillage or flat planting; V1 = Russet Burbank; V2 = Hilite Russet.

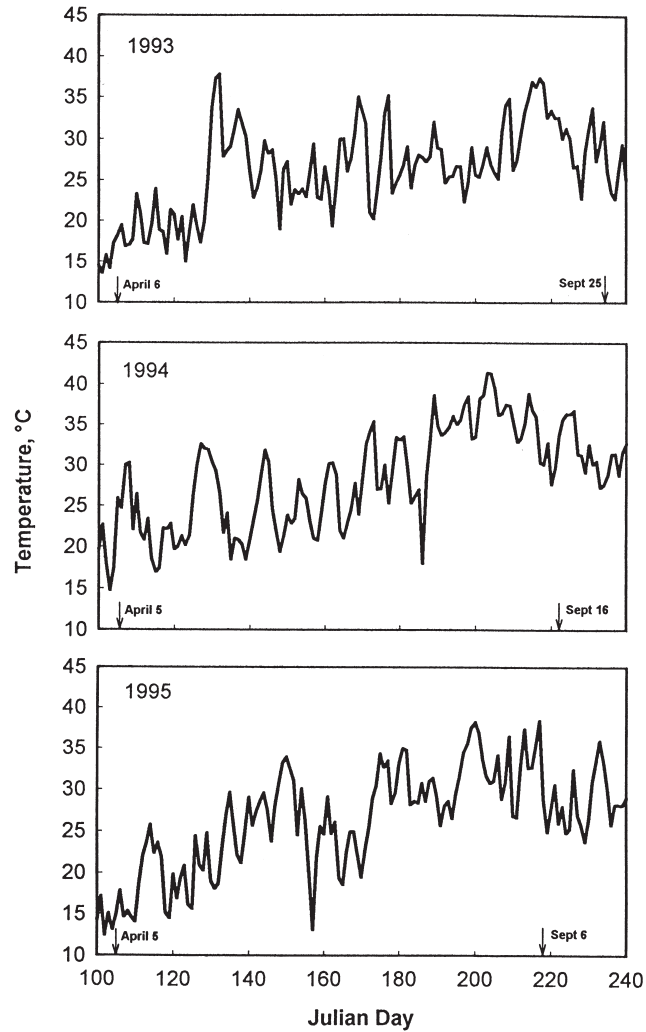


Figure 1. Daily maximum temperature during growing period of potato measured at the study site for three years.

subsequent two years, however, the tuber yields with deficit irrigation treatment (85% ET) were lower by 11 and 8% in Russet Burbank, and by 17 and 10% in Hilite Russet variety as compared to that with irrigation to replenish 100% ET (Fig. 3). Tuber yield appears to be related to climatic factors, such as high temperature during the growing season. Among the three years duration of this

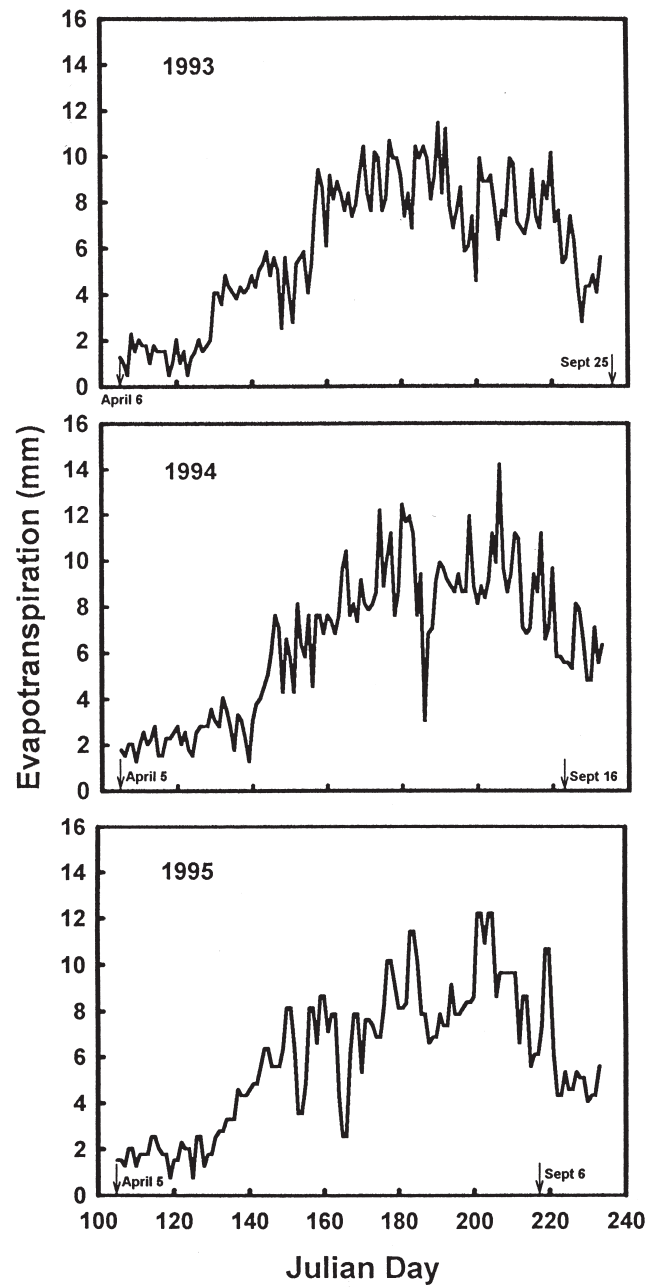


Figure 2. Daily evapotranspiration (ET) data during the growing period of potato measured at the study site for three years.

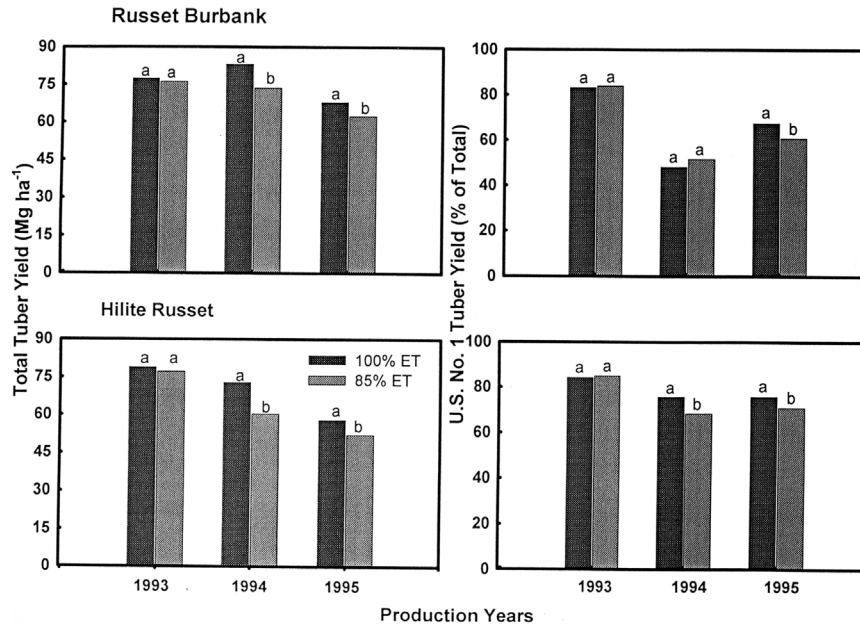


Figure 3. Total tuber yield and percentage of U.S. No. 1 tuber yield of two potato cultivars grown on a Quincy fine sand as influenced by two irrigation regimes over three years. Data averaged over three tillage treatments. Mean yields followed by similar letters within each variety and each year are not significantly different according to least significant difference (LSD) test at $P = 0.05$.

study, 1993 had fewer total days of high temperature conditions compared to 1994 or 1995 (Fig. 1). Accordingly, the ET was lower during the 1993 growing period as compared to that for the 1994 or 1995 growing period (Fig. 2). The effects of irrigation regimes are generally significant under high ET than under lower ET growing conditions. This may, in part, explain the lack of significant differences in tuber yield between the two irrigation treatments during 1993 as compared to the subsequent two years. In 1993, total tuber yield was similar between the two cultivars (Fig. 3). In the subsequent two years, the tuber yield was lower for the Hilite Russet as compared to that for the Russet Burbank cultivar. Furthermore, during 1994 and 1995, the tuber yield was significantly lower in both cultivars in deficit irrigation treatment as compared to that with irrigation to replenish full ET. Tuber quality, in part, determines the marketability and the economic return for the product. A high percentage of U.S. No. 1 tubers is an important quality trait that can increase economic returns. In 1993, U.S. No. 1 tuber yield represented about 80% of total tuber yields of both cultivars

regardless of irrigation treatments. In 1994 and 1995, the percentage of U.S. No. 1 tuber yield was lower for both cultivars as compared to that in 1993. In the case of Russet Burbank, the U.S. No. 1 tuber yield was only about 50% of the total tuber yield in 1994. This could be related to the high temperature conditions during the 1994 growing season.

The tillage effect was non-significant on total or U.S. No. 1 tuber yield of both varieties in 1993 and 1994 (Table 1). However, in 1995, the total tuber yield decreased significantly in the order: conventional > modified > flat planting, for Russet Burbank cultivar, while in the case of Hilite Russet the tuber yield was significantly lower for the flat planting treatment as compared to the modified tillage (Fig. 4). The percent of U.S. No. 1 tuber yield was also not significantly influenced by the tillage treatments in both the cultivars during 1993 and 1994. However, in 1995, the percent of U.S. No. 1 tuber yield was significantly greater in flat planting treatment as compared to the other two tillage treatments for Russet Burbank, while the trend was reversed in the case of Hilite Russet cultivar.

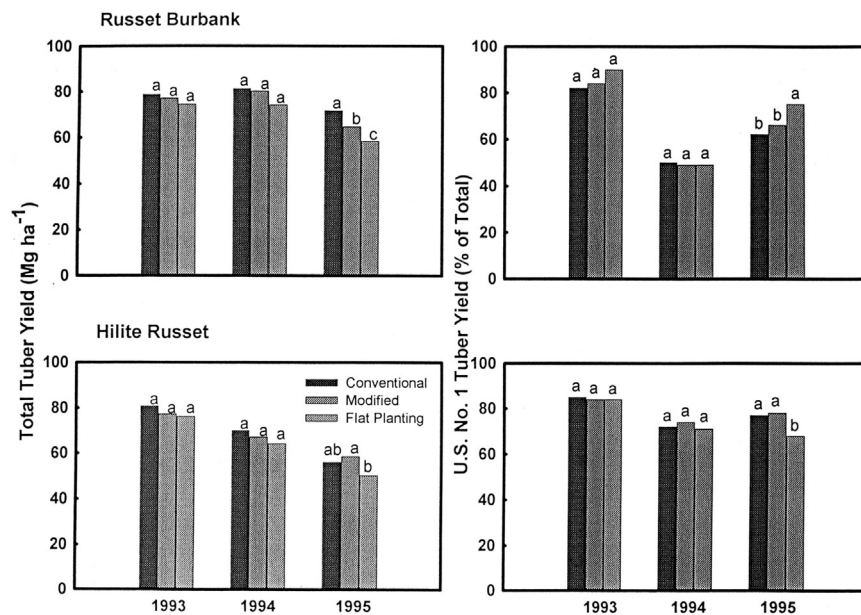


Figure 4. Total tuber yield and percentage of U.S. No. 1 tuber yield of two potato varieties as influenced by three tillage treatments over three years. Data averaged over two irrigation regime treatments. Mean yields followed by similar letters within each variety and each year are not significantly different according to least significant difference (LSD) test at $P = 0.05$.

The results of this study show that either modified tillage or flat planting can be used without sacrificing yield in the soil and climatic conditions prevalent in this region. In the higher latitudes or higher elevations where warming of soil temperature is delayed in the spring, planting into hills may allow faster emergence of potato plants. Reduced tillage systems may improve water and nitrogen use efficiency as less water (and irrigation-delivered chemicals) will be shed off the sides of the hills to enter the soil at the bottom of the furrows, where it is less available to the crop and more liable to leach below the crop root zone. This study demonstrates that under the soil and climatic conditions in the Pacific Northwest, reduced tillage provides a viable option for potato production. The yield and quality of tubers with reduced tillage were comparable to those with conventional tillage in two of three years. In addition to cost reduction, the reduced tillage could offer improved soil quality, and reduced soil and nutrient losses.

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REFERENCES

1. Westermann, D.T. Fertility Management. In *Potato Health Management*; Rowe, R.C., Ed.; APS Press: St. Paul, MN, 1993; 77–86.
2. Westermann, D.T.; Kleinkopf, G.E. Nitrogen Requirements of Potatoes. *Agron. J.* **1985**, *77*, 616–621.
3. Lauer, D.A. Nitrogen Uptake Patterns of Potatoes with High-Frequency Sprinkler-Applied N Fertilizer. *Agron. J.* **1985**, *77*, 193–197.
4. Lauer, D.A. Russet Burbank Yield Response to Sprinkler-Applied Nitrogen Fertilizer. *Am. Potato J.* **1986**, *63*, 61–69.
5. Ojala, J.C.; Stark, J.C.; Kleinkopf, G.E. Influence of Irrigation and Nitrogen Management on Potato Yield and Quality. *Am. Potato J.* **1990**, *67*, 29–42.
6. Joern, B.C.; Vitosh, M.L. Influence of Applied Nitrogen on Potato, Part I: Yield, Quality, and Nitrogen Uptake. *Am. Potato J.* **1995**, *72*, 51–63.
7. Stark, J.C.; McCann, I.R.; Westermann, D.T.; Izadi, B.; Tindall, T.A. Potato Response to Split Nitrogen Timing with Varying Amounts of Excessive Irrigation. *Am. Potato J.* **1993**, *70*, 765–777.

8. Westermann, D.T.; Sojka, R.E. Tillage and Nitrogen Placement Effects. *Soil Sci. Soc. Am. J.* **1996**, *60*, 1448–1453.
9. Thornton, R.E.; Sieczka, J.B. Commercial Potato Production in North America. *Am. Potato J.* **1980**, *57*, 1–36.
10. U.S. Dept. of Health, Education and Welfare, *Public Health Science Drinking Water Standards*; Publ. 956, U.S. Dept. of Health, Education and Welfare: Washington, DC, 1962.
11. SAS Institute, *The SAS System Rebase, Version 6.12*; SAS Institute: Cary, NC, 1996.
12. DeRoo, H.C.; Waggoner, P.E. Root Development of Potatoes. *Agron. J.* **1961**, *53*, 15–17.
13. Lesczynski, D.B.; Tanner, C.B. Seasonal Variation of Root Distribution of Irrigated, Field Grown Russet Burbank Potato. *Am. Potato J.* **1976**, *53*, 68–78.